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THE CHINESE LOESS PUZZLE.

BY PROFESSOR J. D. WHITNEY.

THE appearance of the first volume of Baron F. von Richthofen's magnificent work on China[1] furnishes us with a suitable opportunity to put before the readers of the NATURALIST a brief account of one of the most curiously puzzling geological phenomena which has ever been brought to the notice of the scientific world,—the distribution and mode of occurrence of the so-called loess deposits of Northern China. The term *loess* is one in popular use in the valley of the Rhine for a peculiar loamy material[2] which occurs over a considerable area between Constance and the Belgian lowlands, having in places a thickness of as much as one or two hundred feet, and which is generally admitted to have been a lacustrine deposit, formed when the Rhine was swollen by the melting of the great Alpine glaciers, which then extended much below their present level and covered a far greater area than they now do. Important as this formation is in that region, it sinks into insignificance when compared with what is presented by the Chinese deposits of similar character.

The Chinese loess, like that of the Rhine, is an earthy substance of a brownish-yellow color, so tender and little coherent that it can be easily rubbed to a powder between the fingers. It is chiefly made up of argillaceous materials, with a small proportion of carbonate of lime; and it has also mixed with it more or less fine sand, the grains of which are quite angular. This sand, however, is small in quantity as compared with the argillaceous

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[1] China, Ergebnisse eigener Reisen und darauf gegründeter Studien, Erster Band, Einleitender Theil. Berlin, 1877.

[2] Loess is very nearly the equivalent of the English word loam. Perhaps the best way to define it would be to say that loam when developed enough to become a formation of geological importance, and not a mere surface deposit, is loess.

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portion. The most striking facts with regard to this material in China are its wide-spread distribution and its enormous thickness, — facts which, taken in connection with its composition and structure, render its origin one of the most perplexing of geological problems.

First, as to its distribution. According to Richthofen, this formation is spread over a large part of the region drained by the Hwang-Ho or Yellow River, — a name derived from the color of the material which this great stream is continually carrying in suspension towards the Yellow Sea, in which name we again recognize the coloration given by the particles of the loess, which itself is called by the Chinese *hwang-tu* or yellow earth. For nearly a thousand miles from the borders of the great alluvial plain of Pechele, through the provinces of Shansi, Shensi, and Kansu, everywhere to the north of the Wei, which runs along the northern base of the range of the Tsing-ling-shan, the loess may be followed up to the very divide which separates the basin of the Hwang-Ho from the region destitute of drainage into the sea. Towards the north, it reaches almost to the edge of the Mongolian plateau. Furthermore, it may be observed in the province of Honan, along the south side of the most easterly outliers of the Kwenlun, filling a large portion of the middle part of the basin of the Han, covering large areas in Shantung, and reaching southwards in isolated patches as far as the Yangtse. The area over which the loess spreads itself almost continuously is as large as the whole of Germany ; while it is found in more or less detached portions over an additional area nearly half as large as that empire.

From the known topographical character of the loess-covered region, it will be recognized at once that the formation in question occurs at very varying altitudes, or that it is distributed without regard to the elevation of the surface on which it rests. From near the level of the sea up to six thousand feet and more above it, this characteristic material lies, covering valley and mountain slope, absent only on the crests of some of the higher dividing ridges. This extraordinary range of vertical position has not been given to the loess by changes of level of the land since it was deposited, for Richthofen declares that it clearly results from his researches that the relative position of the higher and lower portions of the region in question has not been changed since the deposition of the loess; although he believes that, as a whole, its eastern border has been depressed in altitude, the coast-line formerly extending farther out into the sea than it now does. So much for the horizontal and vertical distribution of the loess, and now some of its structural conditions may be noticed.

Two peculiarities strike the eye of the observer at once on examining the material in question: in the first place, the entire absence of any indications of stratification; and, second, the tendency which it everywhere exhibits to cleave or crack in vertical planes. These peculiarities, however, would not make such a strong impression on the mind of the geologist if it were not for the enormous thickness of the deposit, which is usually several hundred and in places reaches fifteen hundred or even two thousand feet. To see such a mass of material, not of igneous origin, destitute of any indication of stratification, is something entirely out of the ordinary experience of the geological observer. It would seem impossible that such a deposit could have been laid down except from water, and, if so, where are the lines of deposition, which never fail to make themselves visible in aqueous sediments? The problem, as will be seen, begins to present itself as a puzzle. But it may be asked, Is not this a deposit from water, in which, owing to some peculiar conditions, the lines of stratification have become obliterated? The answer to this is readily given in the negative, when on investigation it is found that this deposit, hundreds of feet in thickness, contains imbedded within its mass no fossil remains of marine or fresh-water origin, but only land shells — mostly those of snails — and occasional bones of land animals. It is evident, then, that this so-called loess is not similar in origin to that of the Rhine Valley, as indeed might easily have been inferred from its position at all elevations over plain and mountain side; but that it is a subaerial deposit.

Apart from theoretical considerations of origin, which make this loess formation so interesting, there are other circumstances resulting from its mode of occurrence, which bear on the daily life of the people inhabiting these loess-covered districts, and so connect themselves with their agriculture, their roads, and their means of military defense as to be abundantly striking, even to the observer who cares nothing for geological problems, and to whom the absence of lines of stratification would not appear as a noticeable fact. The peculiar type of scenery which these great areas, covered by such a thickness of soft, easily eroded material, present could not fail to impress itself on the mind of the most careless observer. And we find that the main features of the landscape in the loess districts are closely connected in their origin with the tendency which this material possesses — as already noticed — to divide into masses separated by vertical planes; a peculiarity which is not properly cleavage, neither is it exactly what geologists call jointing, but something near akin to it. As a result of this tendency, we find that the rivers which run through the loess-covered districts are bordered by absolutely vertical walls of this material, sometimes hundreds of feet in height. Given the elements of great thickness of the deposits, extreme facility of erosion due to the softness of the mass, and the tendency to vertical cleavage, and it can easily be imagined that the resulting forms left from the action of erosive agencies must be extremely complex and peculiar. Indeed, as described by Richthofen, the loess-covered region is certainly one of the most curious portions of the earth's surface. It somewhat resembles the Colorado plateau, in being deeply and intricately furrowed by drainage channels of great depth, and proportionately very narrow. In the Colorado region, however, the walls of the cañons, as these gorges are there called, are never vertical, though usually quite steep, and the material on which the water exercises its erosive power has a greater variety of texture and color than that offered by the loess, which is remarkably homogeneous from top to bottom. The difficulty of traversing such a region, or even of engineering roads through it, can readily be imagined. It is not so much of a task to keep on one main divide between two systems of gorges; but to go across the country in any fixed direction is almost an impossibility. Tunnels and spiral stairways in the mass of the loess must often be resorted to. In short, the configuration of the surface is, as Richthofen remarks, most fantastic and curious. "Wide chasms are surrounded by castles, towers, peaks, and needles, all made up of yellow earth, between which gorges and chasms radiate labyrinthically upwards into the walls of solid ground around. High up on a rock of earth, steeper than any rock of stone, stands the temple of the village, or a small fortress which affords the villagers a safe retreat in times of danger. The only access to such a place is by a spiral stairway dug out within the mass of the bluff itself. In this yellow defile there are innumerable nooks and recesses, often enlivened by thousands of people, who dwell in caves dug out in the loess.[1]"

Millions of human beings live in habitations excavated in this material. These dwellings vary in character from mere holes in the ground to commodious mansions. The largest houses for the entertainment of travelers are sometimes excavated to a distance of two hundred feet into the ground, with corresponding breadth and height, so that numerous guests, with their vehicles and animals, can be housed with comfort, small side apartments being cut out adjacent to the large one for sleeping quarters. The walls of these extraordinary dwellings are lined with cement made from the calcareous nodules which the loess often contains; this arrangement tends to cleanliness and durability, and dwellings thus protected sometimes last for hundreds of years, being warm in winter and cool in summer. It must be a most curious experience to travel over the surface of a highly cultivated loess district, and to see no signs of any inhabitants, until one comes to some point where the vertical wall of yellow earth is exposed to view, in and out of the holes in which the people are seen swarming like bees around a bee-hive. To the traveler looking down from an adjacent elevation on to one of the loess basins, the surface seems uniform in character with a gently descending slope, easily accessible and green with vegetation; from the bottom of one of the gorges, on the other hand, only the bare, vertical loess walls are visible, while the whole mass is found to be intersected with a labyrinth of deep and, from the general level, inaccessible gorges.

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[1] Richthofen, Letter on the Provinces of Chili, Shansi, Shensi, and Sz'-chwan. Shanghai, 1872.

Such are some of the more striking peculiarities of the loess formation. But, besides its tendency to vertical cleavage, it exhibits a more or less complete arrangement in thick layers, and this has been taken by some observers for a real stratification, which, however, as Richthofen considers that he has clearly established, it is not. This pseudo-stratification depends for its existence on horizontal lines of calcareous concretions, like what we call clay-stones, the *Loessmännchen* of the dwellers on the Rhine, and which the Chinese call by a name which means "stone ginger," from the resemblance of these concretionary forms to the roots of the ginger plant. That these loessmännchen have been formed in the loess by infiltration along the lines of cleavage and resultant chemical action on calcareous matter occurring in large quantity along certain planes, and that they are not the product of anything like deposition from water, is clearly shown by their vertical position in the material in which they are found; had they been swept into their places by a current of water, they must have been laid upon their flat surfaces. These imperfectly formed concretionary layers exercise an important influence in determining a terrace-like form of the sides of the gorges worn down in the loess, which often rise in a succession of steps, having this peculiarity: that there is little or no talus or sloping pile of débris along the line where the vertical and horizontal surfaces meet. The natural tendency to this condition of things is assisted in its development by the labors of those who cultivate the soil, and for whose advantage it is to gain as much flat surface as possible.

The first person to notice and describe these remarkable deposits was Professor Pumpelly, who, in 1864, journeyed over a portion of the loess-covered districts lying along the southern border of Mongolia. His observation, however, did not, by any means, extend over so wide an area as those of Richthofen, and his theory of the origin of the loess appears to be insufficiently supported by the facts which a much larger and more exhaustive investigation of the country brought to light; still, it must be admitted that there are difficulties which no theory seems able fully to overcome. Professor Pumpelly considered the loess, which he describes under the name of "terrace deposit," as a lacustrine formation, each of the basins in which this material occurs having been once the bed of a lake, a series of large bodies of fresh water being assumed as formerly extending along the course of the Hwang-Ho, which did not then occupy its present position, but ran in a pretty direct line, connecting the different basins, from Ning-hia-fu to Peking. This theory, therefore, demands that there should have been a considerable diminution in the quantity of water formerly covering the region in question. It seems the most plausible one at first sight, however, and other observers — as for instance Kingsmill — have not hesitated to adopt and defend it.

The difficulties which this theory presents seem, as developed by Richthofen, almost, if not quite, insurmountable. The main arguments urged against Pumpelly's theory will be readily inferred from what has been stated in the preceding paragraphs. The absence of indications of stratification, and the constant presence in the material of land instead of fresh-water shells, and of bones of land animals, are facts which it seems impossible to set aside, since they result from prolonged observations made by a most skillful geologist. Besides, the loess indicates by its structure the growth on its surface during deposition of an abundant vegetation. The plants themselves — grasses, chiefly — are no longer there; but the constant occurrence of innumerable delicate, elongated cavities, occupying a nearly vertical position, ramifying and inosculating at very acute angles, just as do the rootlets of plants, shows their former presence. It is to this peculiarity that the tendency to vertical cleavage, which is so conspicuously manifested in the loess, is largely due.

There is a greater difficulty still, if possible, in the way of the adoption of the lacustrine origin of these deposits. As Richthofen declares with the utmost confidence, based on a thorough examination of the region, the loess everywhere exhibits itself as a deposit which was not laid down until after the surface of the country where it occurs had assumed its present configuration. The orographic conditions are not such as, by any possibility, could allow of the formation of a connected series of lake-like expansions of the Hwang-Ho, as is demanded by Professor Pumpelly's theory.

Richthofen, therefore, unhesitatingly declares himself in favor of a subaerial origin of the loess; and he endeavors to account for the accumulation of this enormous mass of material in the following manner. In the first place, and as a necessity of the proposed theory, the district of the loess was once destitute of outward drainage, consisting, in fact, of a number of closed basins, such as are still found occurring in the adjacent region to the west in Central Asia. These closed basins were prairies, and the loess is "the collective residue of uncountable generations of herbaceous plants." It is the inorganic residuum which has accumulated during an immense lapse of time as the result of the decay of a vigorous prairie growth, ever renewing itself on the surface of the slowly accumulating deposit. But how is the increase of the deposit provided for by the theory? Unless there be some source supplying material from without, there can evidently be no gain in thickness, however many generations of plants succeed each other. The necessary addition of mineral matter Richthofen considers to have been brought into these basins by two agencies, the rain and the wind, and the latter especially plays an important part in this theory. Each basin being surrounded by a rim of rocks, constantly undergoing decomposition, the particles thus set free were either swept down the mountain sides towards the central area by rain, or blown thither by air currents, and once entangled among the vegetation could not be carried farther.

The facts being assumed to be as Richthofen states them, it would appear that no other theory than this can be adopted for their explanation. A marine origin is rendered impossible by the absence of marine fossils, the constant presence of land shells and bones of land animals, as also by the absence of stratification and the very great differences of level at which the formation rests. The same arguments apply to the theory of a lacustrine origin, except that the one last mentioned would not present insuperable difficulties, or at least not any greater ones than those which the adoption of Richthofen's views implies. Either theory seems to need for its support changes of climate and a certain amount of alteration in the configuration of the surface. If the loess were deposited in closed basins, these are now opened to the sea and drained by the Hwang-Ho. The areas once separated from each other are at present connected; the deposits they inclosed are now being swept away to the sea. It is impossible to account for this changed condition of things without admitting a considerable increase in the amount of precipitation over the region in question, and it is not easy to see how a complete drainage system could have been established without the formation of a certain number of lakes, nor why these should all have disappeared so completely. According to the lacustrine theory, on the other hand, the precipitation is now less than it formerly was; the mighty lakes have shrunk and disappeared, the Hwang-Ho is but the remnant of what was once a much larger stream. What change of level in the area thus drained would be required to fit this theory it seems difficult to make out. The appearance, in a future volume of Richthofen's great work, of the details of the cartography and geology of the region in question will, no doubt, be of much assistance in enabling one to form a clearer opinion of these matters. The interesting chapter in the volume already published, entitled Formation and Remodeling (Bildung und Umbildung) of the Salt Steppes of Central Asia, in which subjects closely connected with the question of the mode of formation of the loess are discussed at very considerable length, cannot at present be entered upon, for want of space. Its consideration may be taken up at a future time, when it will be found that it has important bearings on certain points closely related to our own surface geology, and which have not yet received anything like the attention which they deserve at the hands of our geological observers. It is sufficient, for the present, to have given the readers of the NATURALIST an idea of one among the many interesting topics treated in Richthofen's work. It should be added, however, that the contents of the only volume as yet published refer chiefly to the historical development of geographical discovery in China and Central Asia, forming by far the most copious and thoroughly digested summary of facts ever as yet presented relating to this interesting but difficult subject.

THE COLORS OF ANIMALS AND PLANTS.[1]

BY ALFRED RUSSEL WALLACE.

I. THE COLORS OF ANIMALS.

Theory of Sexual Colors. — In Mr. Darwin's celebrated work, The Descent of Man and Selection in Relation to Sex, he has treated of sexual color in combination with other sexual characters, and has arrived at the conclusion that all, or almost all, the colors of the higher animals (including among these insects and all vertebrates) are due to voluntary sexual selection ; and that diversity of color in the sexes is due, primarily, to the transmission of color-variations either to one sex only, or to both sexes, the difference depending on some unknown law, and not being due to natural selection.

I have long held this portion of Mr. Darwin's theory to be erroneous, and have argued that the primary cause of sexual diversity of color was the need of protection, repressing in the female those bright colors which are nominally produced in both sexes by general laws; and I have attempted to explain many of the more difficult cases on this principle (A Theory of Birds' Nests, in Contributions, etc., page 231). As I have since given much thought to this subject, and have arrived at some views which appear to me to be of considerable importance, it will be well to sketch briefly the theory I now hold, and afterward show its application to some of the detailed cases adduced in Mr Darwin's work.

The very frequent superiority of the male bird or insect in brightness or intensity of color, even when the general tints and coloration are the same, now seems to me to be due to the greater vigor and activity and the higher vitality of the male. The colors of an animal usually fade during disease or weakness, while robust health and vigor add to their intensity. This intensity of coloration is most manifest in the male during the breeding-season, when the vitality is at a maximum. It is also very manifest

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[1] From Macmillan's Magazine. Concluded from page 662.